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IMPROVEMENT OF SINTER PRODUCTIVITY BY DRY PARTICLES ADDITION ON GRANULATED RAW MATERIALS (DEVELOPMENT OF RF-MEBIOS PROCESS)[1]

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Abstract

In order to increase the permeability of the sintering bed for sinter ore productivity, the RF-Mebios (Return Fine - Mosaic Embedding Iron Ore Sintering) process, in which dry particles are added to granulated raw materials and then they are charged into a sintering machine, is proposed. In RF-Mebios, it is demonstrated by pot tests that sinter productivity increases at the same moisture content in sinter mixture at charging. This productivity increase is caused by higher permeability due to two major phenomena. One is by increasing the pseudo-particle size at granulation and the other is by decreasing the bulk density of the sinter packed bed after charging. The former is achieved by a higher moisture content in the raw materials at granulation. The latter is achieved by higher friction in the packed bed composed of dry and wet particle compounds. In the development of RF-Mebios, return fines were chosen as the dry particle because it is dry when produced by the sintering machine. The sinter productivity increases with the increase of the quantity of the return fines added after granulation. Moreover, RF-Mebios method is installed on three commercial sintering machines (Kashima, Wakayama, and Kokura) belonging to Sumitomo Metals. In all three sinter plants, increasing productivity has been confirmed. Therefore, introducing RF-Mebios has been demonstrated to cause a universal improvement of sinter productivity.

Key words: Sinter productivity; Granulation; Return fines; RF-Mebios.

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1 INTRODUCTION

The recent increase in the amount of fine ore, such as Brazilian concentrated ultra fine, in the raw material of sinter ore lowers the permeability of the sintering bed and the yield of the sinter ore. The collapse of voids in the sintering bed will cause problems although the bed has a porous structure. A pre-granulation technique has been developed and applied to such fine ore[1]. Recently, controlling the bed structure by including loosely packed parts and densely packed parts in the same packed bed has been discussed[2-4]. This new idea is named Mebios (Mosaic Embedding Iron Ore Sintering)[5]. The schematic view of the sintering bed structure of the Mebios method is shown in Figure 1. The purpose of the Mebios method is making a high density but high permeability packed bed by setting denser parts and looser ones in the same packed bed. For example, high-density large green balls, with a diameter of 5 to 15 mm, are placed in the packed bed to make lower density parts around the balls by a "wall effect" so that the permeability of the packed bed increases.

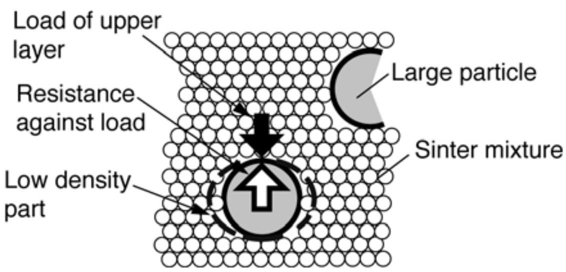

Figure 1. Denser parts and looser ones in the same packed bed of Mebios.[5]

However, to employ this process it is necessary to install a pan pelletizer for generating large (5-15mm) and dense green ball.
The application of Mebios with a low price capital investment has to be developed for product competitiveness. Finally, it is confirmed that even small dry particles charged into the sinter packed bed has a similar effect on controlling the bed structure due to friction between dry particles and wet particles. In addition, the moisture content can be controlled at granulation and at charge into the sintering bed individually, which has the effect of improving granulation. For a commercial sinter plant, return fine is used as the dry particle by bypassing the mixing and granulating route. So, this process is named RF-Mebios (Return Fine - Mosaic Embedding Iron Ore Sintering). Utilization of return fine as the dry particle functions by eliminating the drying process because return fine is utilized as raw materials soon after it is discharged from sintering machine.
In this report, from the view point of bulk density in the sinter packed bed and pseudo-particle size after mixing and granulation, permeability improvement techniques based on RF-Mebios were studied fundamentally by pot test. After that, it has been applied in three sinter plant in SMI (Kashima, Wakayama, Kokura) and productivity has been improved in each sinter plant.

2 FUNDAMENTAL STUDY FOR PERMEABILITY IMPROVEMENT (POT TEST)

2.1 Experimental

Figure 2 shows the experimental flow of the pot test. At first, 85mass% of raw materials, which were fine ore and limestone, and 15mass% of return fines were prepared. Then the raw materials except some part of the return fines (X%) were

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mixed in a drum type mixer for 4 min, and a certain amount of water was sprayed in, and mixed for 4 min. The mixing after water spraying causes granulation. Then the return fine (X%) was added into the granulated sinter raw materials and mixed in the drum type mixer for 15 seconds. After that, they were charged into a pot, which has a diameter of 300mm and height of 500mm, to compose the packed bed. X value, which is the proportion of the bypass return fine, is varied in 5% increments from 0% to 15%. The moisture content was measured after granulation and at charging. And the moisture content at charging was constant (7.0%). Thus with an increasing X value, the moisture content after granulation increased.

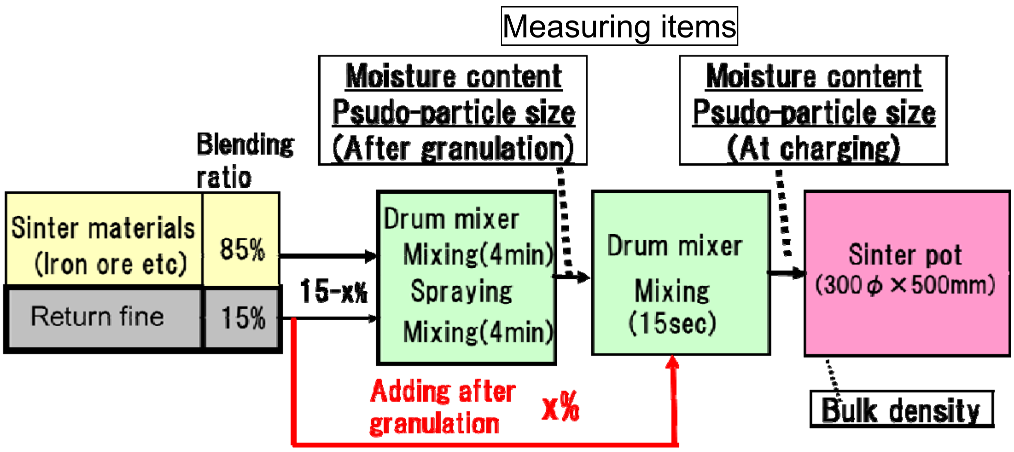

Figure 2. Experimental flow of pot test (300φ).

Figure 3 shows the relation between the bypass return fine ratio and the moisture content after granulation and at charging for designed and actual values. Actual values were matched with the designed one.

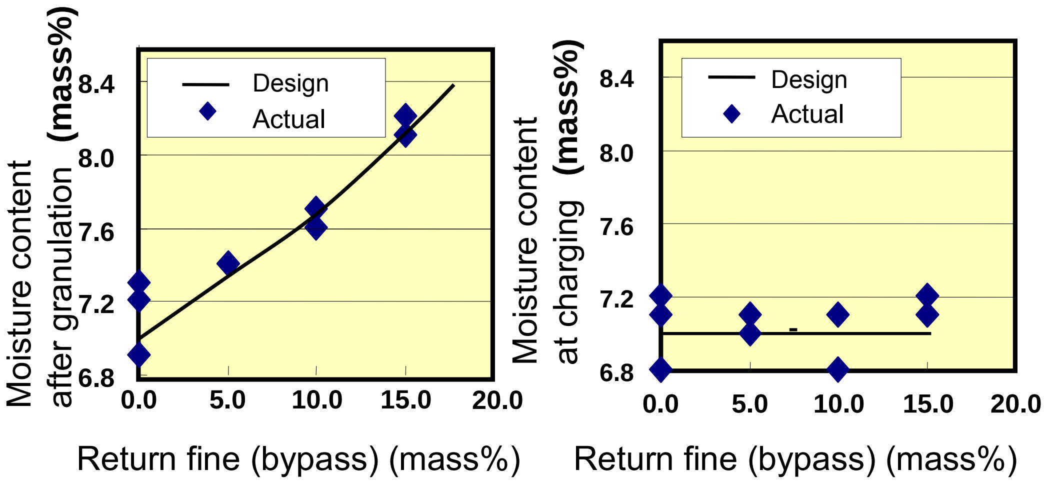

Figure 3. Moisture content in sinter raw materials after granulation and at charging.

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Furthermore, another experimental condition is shown in figure 4. Return fine was previously sieved to 5 mm. And in the experiment return fine of several sizes were added after granulation.
Pseudo particle size was also measured both after granulation and at charging. After charging into sintering pot, bulk density was measured.

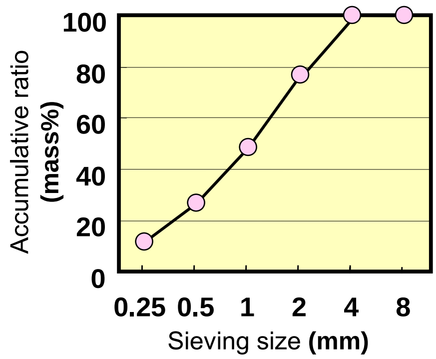

Figure 4. Size distribution of return fine.

The blending condition is shown in Table 1. The purpose of series 1 and series 2 is to investigate the return fine amount and the return fine size bypassing granulation, respectively. 5 kinds of major iron ore fines in Japan were used. The coke breeze blending ratio was 4.5% of the total raw materials. In series 2, the blending ratio of return fine(+1mm) and return fine(-1mm), which were 7.7% and 7.3% respectively, corresponds to the size distribution of return fine shown in figure 4, where -1mm ratio in it is 49% .

Table 1. Blending condition

Route	Raw materials	Series 1				Series 2	
Ordinary Route	Iron ore R	8.5	8.5	8.5	8.5	8.5	8.5
	Iron ore Y	19.1	19.1	19.1	19.1	19.1	19.1
	Iron ore H	13.2	13.2	13.2	13.2	13.2	13.2
	Iron ore C	8.5	8.5	8.5	8.5	8.5	8.5
	Iron ore W	21.3	21.3	21.3	21.3	21.3	21.3
	Serpentine	2.1	2.1	2.1	2.1	2.1	2.1
	Lime stone	12.3	12.3	12.3	12.3	12.3	12.3
	Return fine	15	10	5	0	-	-
	Return fine(+1mm)	-	-	-	-	-	7.7
	Return fine(-1mm)	-	-	-	-	7.3	-
	Sub Total	100	95	90	85	92.3	92.7
	Coke breeze (-5mm)	[4.5]	[4.5]	[4.5]	[4.5]	[4.5]	[4.5]
Bypassing granulation route	Return fine	***0***	***5***	***10***	***15***	-	-
	Return fine(+1mm)	-	-	-	-	***7.7***	-
	Return fine(-1mm)	-	-	-	-	-	***7.3***
	Sub Total	***0***	***5***	***10***	***15***	***7.7***	***7.3***
Total		100	100	100	100	100	100
	Coke breeze (-5mm)	[4.5]	[4.5]	[4.5]	[4.5]	[4.5]	[4.5]

2.2 Results

Figures 5 through 7 show the results for productivity, FFS, and yield, respectively. With the increasing ratio of bypass return fine, productivity and FFS increased.
And bypassing large (+1mm) particles were better compared with bypassing small (-1mm) particles.

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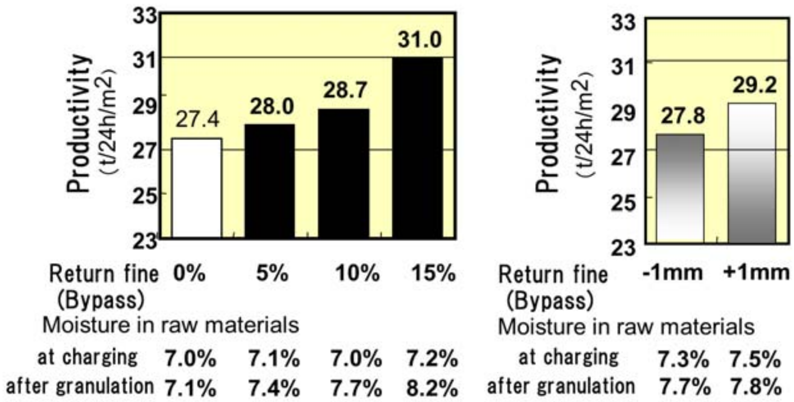

Figure 5. Improvement of productivity by return fine bypass.

In the case of 15% return fines bypass, the pot yield was decreased. Excess high FFS caused a decrease of yield.

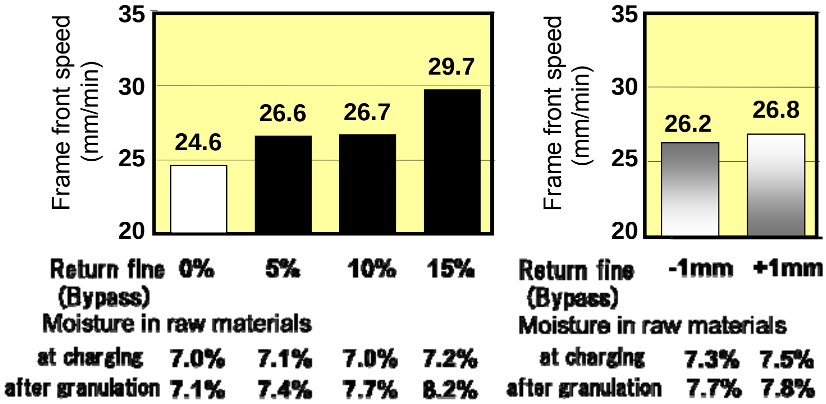

Figure 6. Effect of return fine bypass on FFS by return fine bypass.

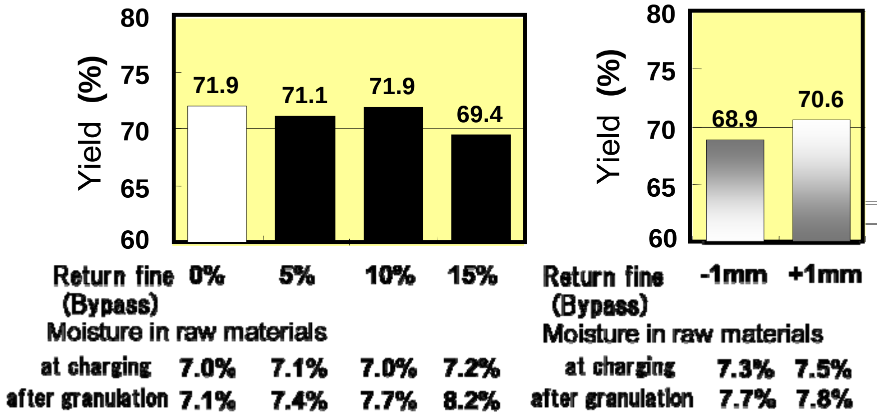

Figure 7. Influence of return fine bypass on yield.

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The bulk density and pseudo-particle size (-0.25mm) is shown in Figure 8. With decreasing ratio of bypass return fine, the bulk density and pseudo-particle size (-0.25mm) decreased. And large (+1mm) particle bypass shows a slightly smaller values compared with small (-1mm) particle bypass.

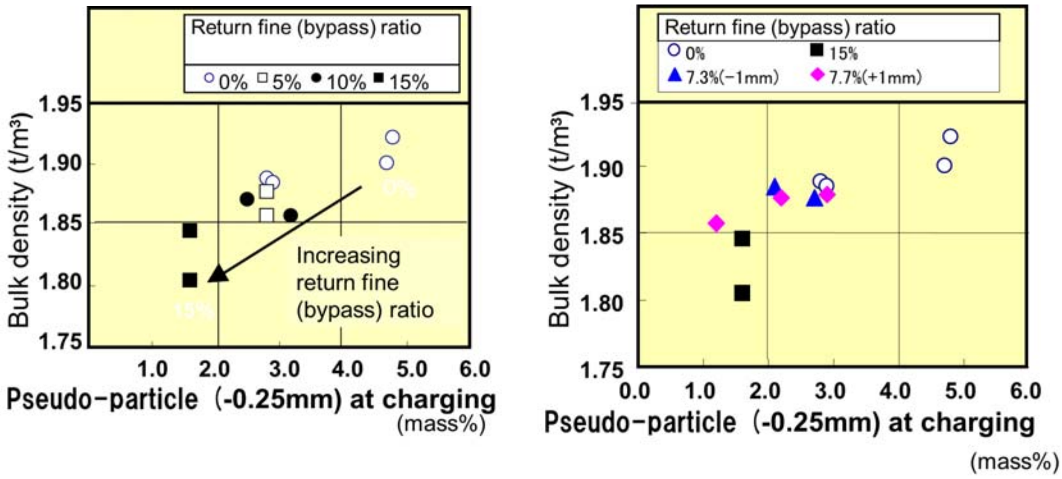

Figure 8. Effect of yield by return fine bypass on bulk density and pseudo-particle size.

To summarize the results, adding dry return fines to granulated raw materials under the condition at which moisture content after adding is equal, pseudo-particle size (-0.25mm) decreases due to higher moisture granulation.
In addition, the bulk density decreases if the mixture includes dry particles. It is assumed that friction between particles contributes to low bulk density.

2.3 Consideration

Generally, the permeability of the particle packed bed is a function of pore ratio and particle size as in the Ergun Equation. In addition, FFS is a function of moisture content in materials and permeability, because the flame front of carbon ignition depends on moisture vaporization. In fact, from figure 8, decrease of bulk density and pseudo-particle (-0.25mm) were confirmed at a high ratio of return fine bypassing granulation. The bulk density corresponds to pore ratio and pseudo-particle (-0.25mm) ratio is a parameter of particle size in sinter packed bed. And so it is clear that the decrease of the two parameters strongly influences high flame front speed.
Quantitative evaluation for effect of pore ratio and pseudo-particle (-0.25mm) ratio on flame front speed is considered as follows.
Our previous study[6,7] of examination for effects of FFS increase by pore ratio and pseudo-particle size has resulted in formula as below.

$$\text{FFS(mm/min)} = 86.67\,(1 - 0.247([\text{Pseudo-particle(-0.25mm)(\%)}])/100)\,(1-3.20([\text{moisture content at charging (\%)}]/100)(\varepsilon^3/(1-\varepsilon))^{0.6}+2.33 \cdots \text{(a)}$$

In this formula (a), the former term corresponds to convection heat transfer between gas and a particles, depending on the pseudo-particle (-0.25mm) ratio, moisture content at charging, and the pore ratio (ε), and the latter term corresponds to heat transfer directly between particles.
Based on formula (a), the effect of the pore ratio (ε) and the pseudo-particle (-0.25mm) ratio on flame front speed are evaluated individually as broken lines in

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Figure 9. The inclination of these broken lines reflect the former term in formula (a), substituting data in the case of 0% of “return fine bypassing” for pseudo-particle (-0.25mm) ratio, moisture content at charging, and (ε). The effect of (ε) and the pseudo-particle (-0.25mm) ratio on the flame front speed were evaluated as 41% and 55% of the increase to the frame front speed, respectively.

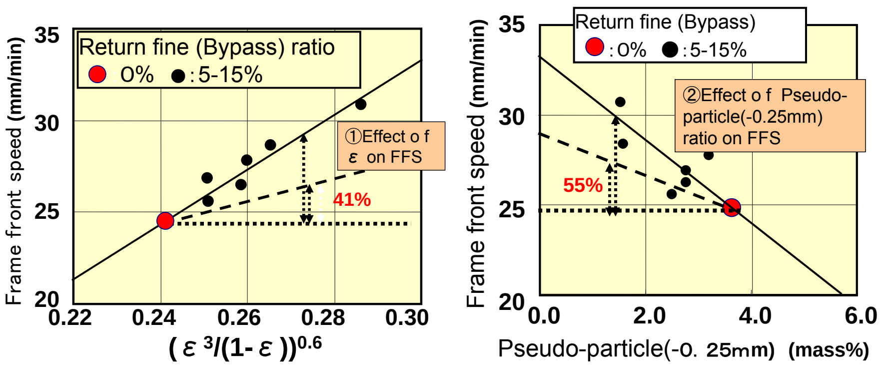

Figure 9. Quantitative analysis for FFS increase by pore ratio and pseudo-particle size.

Figure 10 shows the mechanisms by which the return fine bypassing granulation route improves productivity. While the moisture content at charging remains constant, the return fine bypassing granulation route results in an increase of moisture content after granulation. In spite of small particles (-0.25mm) in the return fines bypassing granulation route, the pseudo-particle (-0.25mm) ratio at charging in the sinter machine decreases due to high moisture granulation. In addition, the bulk density is decreased by dry return fine addition into granulated wet particles. Both the decrease of pseudo-particle (-0.25mm) ratio at charging and the decrease of the bulk density contribute to improving productivity.

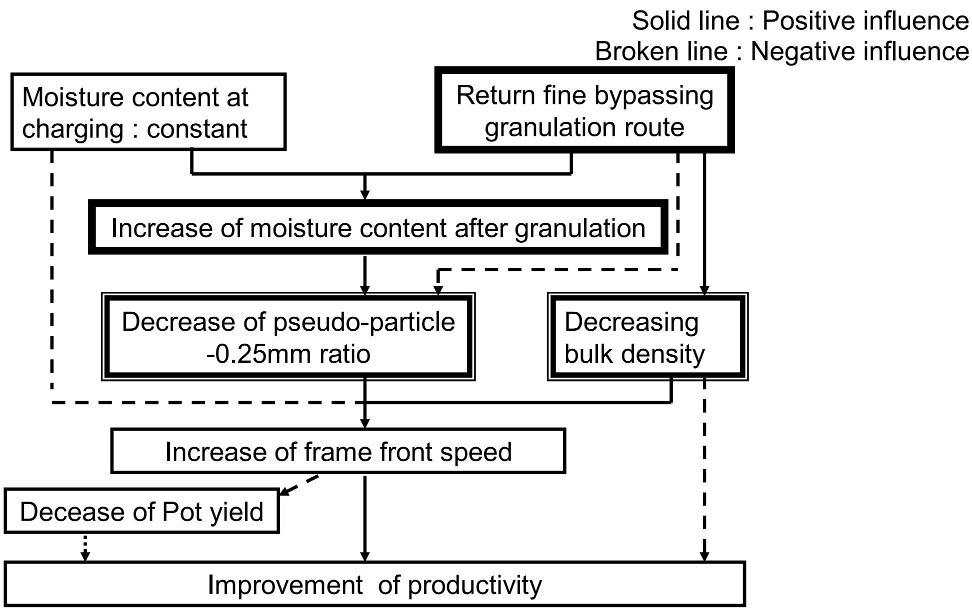

Figure 10. Effect of RF-Mebios (Return fine bypassing granulation route) on improvement of productivity.

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3 PRACTICAL APPLICATION AT A COMMERCIAL PLANT

3.1 Application at Kashima No.3 Sinter Plant

3.1.1 Layout of return fine transportation

The material flow is shown in Figure 11. Transportation of return fines diverges into two routes. One is to the return fines bin and the other is to the return fines (bypass) bin.

In the return fines bin, return fines and others inter raw materials are mixed together with water in mixer. Return fines from return fines (bypass) bin are added after the mixer, bypassing the mixer.

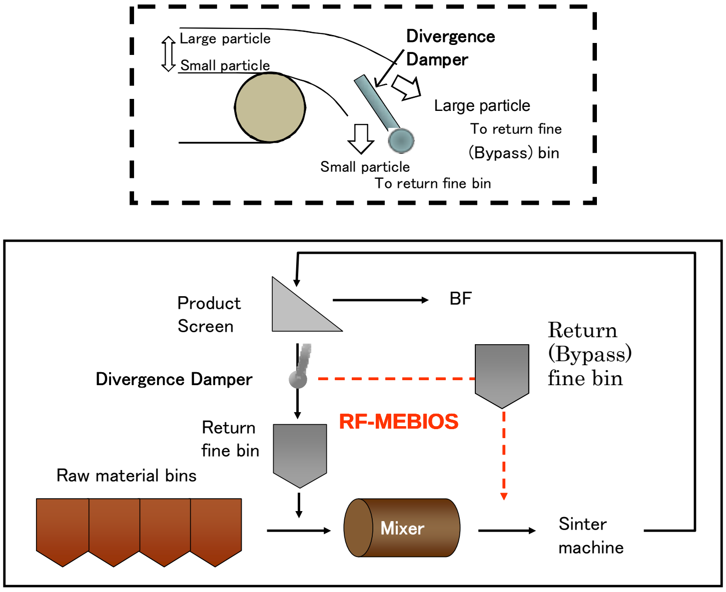

Figure 11. Layout of return fine at commercial sinter plant.

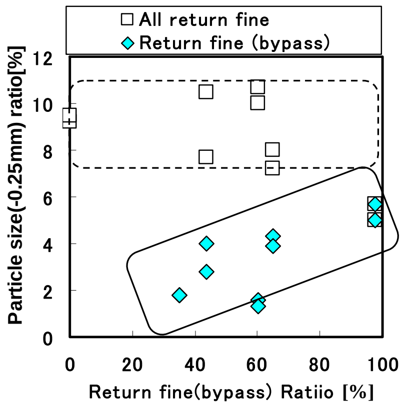

Figure 12. Influence of return fine (bypass) ratio on particle size.

The damper position is adjusted to control the proportion of return fines bypassing the mixing stage. This damper can separate fines between the upper layer and the lower layer so that relative large particles can be transported to the return fines (bypass) bins. This feature is based on result of the pot test, in which large particles bypassing the mixer had superior productivity compared with small particles bypassing. Figure 12 shows the influence of the ratio of return fines bypassing mixer on particle size. When the ratio is low, small particle (-0.25mm) proportioning of

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return fines bypassing mixer is low. Thus large particle proportioning was high. And with an increasing of the ratio, particle size is close to that of total return fine.

3.1.2 Operational results

Transportation of return fines is diverged into two routes. The ratio of return fines bypassing granulation varied and it was tested under three conditions of 20%, 15%, and 8%. The operational results are shown in Figure 13. A high ratio of return fines bypassing granulation causes high productivity (>620t/h) due to high FFS.

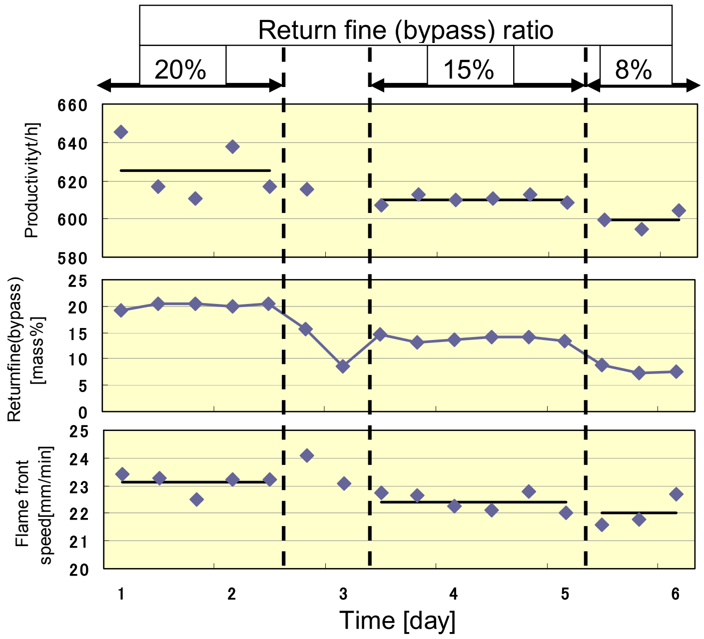

Figure 13. Operational performances at varying return fine bypassing granulation ratio.

Figure 14 shows the effect on granulation of return fines bypassing. Moisture content at charging into the sinter plant was designed to retain the same value. Therefore, high return fines bypassing granulation results in high moisture content (%) in sinter raw materials at granulation. The GI (Granulation Index) was higher at a high ratio of return fines bypassing due to a high moisture content (%) granulation. At charging into the sinter pallet, GI decreased due to adding return fines including small particles, but kept higher than low moisture content (%) granulation at a low ratio of return fines bypassing.

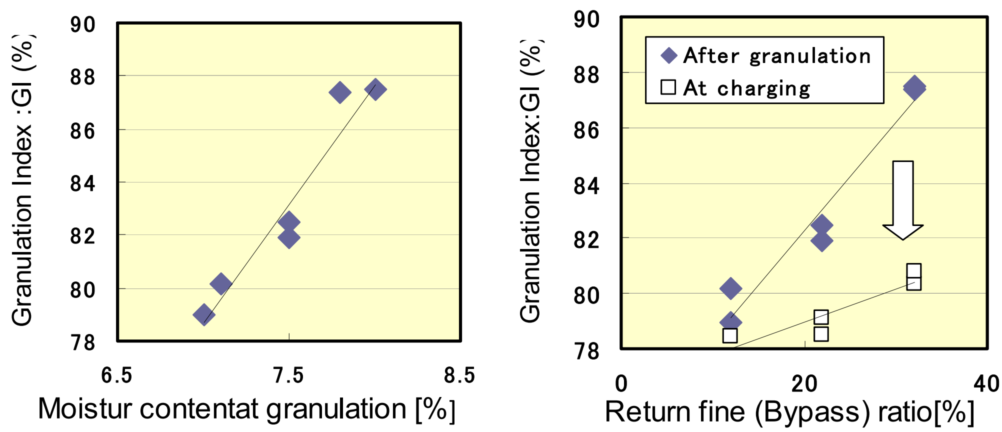

Figure 14. Increasing GI by high moisture content at return fine bypassing granulation.

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3.2 Evaluation at Commercial Plant

RF-Mebios, which is the technique of return fine bypassing granulation, has been applied in three sinter plants. The effect of RF-Mebios on productivity was proved in all three sinter plant as shown in Figure 15.
Thus, the universal effect of RF-Bebios on productivity has been proven.

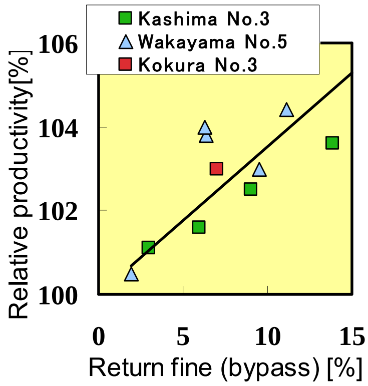

Figure 15. Universal effect of RF-Mebios on productivity.

3.3 Historical Transition of RF-MEBIOS Development

Sumitomo Metals has five sinter plants in three steel works: Kashima, Wakayama, and Kokura. In three sinter plant RF-Mebios has already been implemented. In addition, the fourth implementation will soon be achieved at Kashima No.2 Sinter Plant.

Table 2. Historical transition of RF-Mebios development

	2004-2006	2007	2008	2009	2010	2011	2012	2013
Research (Fundamental and application study)	← - · - ·	- · - ·	- · - →					
Kashima No.2								(⟶)
Kashima No.3		←···→		———	———	———	———	——→
Wakayama No.4								
Wakayama No.5			———	———	———	———	———	——→
Kokura No.3			←···→				———	——→

←···→ Trial operation in short period with temporary equipment
——→ Operation with permanent equipment

4 CONCLUSIONS

The high permeability of the sinter packed bed for sinter productivity improvement has been achieved by the RF-Mebios (Return Fine - Mosaic Embedding Iron Ore Sintering) process, in which dry return fines are added to granulated raw materials. This process improves sinter productivity.

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The high permeability increase is caused by two factors, which are the low fines pseudo-particle (-0.25mm) ratio and the low bulk density. The former is caused by granulation with a high moisture content due to dry return fines addition after granulation. The latter is likely caused by low friction between dry return fines and wet granulated particles.
These techniques have been applied in three Sumitomo Metal Industries, Ltd. sinter plants and an improvement of productivity has been confirmed in the all three plants.

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